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A renewable perspective for sustainable energy development in Turkey: The case of small hydropower plants

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Abstract

Renewable energy resources provide a large share of the total energy consumption of many developing countries. Turkey's renewable sources are the second largest source for energy production after coal. About two-thirds of the renewable energy produced is obtained from biomass, while the rest is mainly from hydroelectric energy. Hydropower is today the most important kind of renewable and sustainable energy. In Turkey, most of the important water power plants have been developed; hence, only a modest increase in the hydroelectric generating capability can be anticipated in the next two decades. Turkey has a gross annual hydro potential of 433,000 GWh, which is almost 1% of world total potential. Its share is about 16% of the total hydropower capacity in Europe. The total gross electricity production of Turkey has reached about 140,283 GWh in 2003, 75% of this is produced from thermal sources and the reminder 25% from hydropower. The main objective in doing the present study is to investigate the sustainable development of Turkey's small hydropower (SHP) plants. Development of SHP began in 1902 in Turkey. Total installed projects capacity of SHP plant is 2.45% and the total energy potential is about 2.96%, which have installed capacity less than 10 MW.
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Keywords: Turkey; Electricity generation; Hydropower; Small hydropower

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Contents

1. Introduction

Renewable energies have been the primary energy source in the history of the human race [1]. Renewable energy sources have some advantages when compared to fossil fuels [2]. Increased use of renewable energy can have an important environmental effect. Nevertheless, few if any of the environmental externalities of energy use are incorporated into their cost, and this is one of the reasons that renewables cost more than competing energy sources. Energy technologies drawing on renewable energy avoid the severe environmental impacts of the fossil fuel cycle [3].

Renewable technologies, like water and wind power, probably would not have provided the same fast increase in industrial productivity as fossil fuels did [4]. Renewable energy resources provide a large share of the total energy consumption of many developing countries [5].

Renewable energy is accepted as a key source for the future, not only for Turkey, but also for the world [6]. Turkey has a considerably high level of renewable energy resources that can be a part of the total energy network of the country [6,7]. Turkey's renewable sources are the second largest source for energy production after coal. About two-thirds of the renewable energy produced is obtained from biomass, while the rest is mainly from hydroelectric energy [8].

Renewables such as solar, wind, hydropower and biogas are potential candidates to meet global energy requirements in a sustainable way [9]. Hydropower is today the most important kind of renewable and sustainable energy [10]. The position of hydro plants becomes more and more important in today's global renewable technologies. The small-scale renewable generation may be the most cost-effective way to bring electricity to remote villages that are not near transmission lines. In the new millennium demand for electricity is expected to increase more rapidly than demand for other forms of energy [11].

Untouched hydropower potential is identified in developing countries of South and Central Asia, Latin America, and Africa, but also in Canada, Turkey and Russia. In Western Europe and the US, the additional hydropower potential is limited, because of advanced development but also due to environmental and political reasons [12]. The world hydropower potential is given in Table 1 [13].

Hydro electric energy is worldwide responsible for some 2600 terawatt-hours (TWh) of electricity output per year, which means about 20% of the world's entire electricity demand being one of the most reliable and cost effective renewable energy source [11]. In

Table 1
Hydroelectric potential of the world [13]

	Gross theoretical potential of HEPP (GWh/year)	Technically viable potential of HEPP (GWh/year)	Economically viable potential of HEPP (GWh/year)
World	40,150,000	14,060,000	8,905,000
Europe	3,150,000	1,225,000	800,000
Turkey	433,000	216,000	127,381

developing countries hydropower is expected to be the fastest-growing renewable energy source. Hydropower is critically important for many countries; hydropower produces more than 50% of electricity for 65 countries [14]. The largest hydropower producer is Canada, followed by the United States and Norway. In 2001, the largest hydropower generating countries were Canada (333.0 TWh), the United States (201.2 TWh) and Norway (120.4 TWh). Other big hydropower producers are Japan, Sweden and France [15].

2. Turkey's hydropower potential and its development

In Turkey, real construction of the dams started after the end of the Second World War except for a few small dams that had been built for irrigation purposes. Since then, the construction of dams and hydroelectric power plants (HEPPs) has increased to realize irrigating and generation electricity project as a result of developmental requirement. However, developments of small hydropower (SHP) projects are neglected due to priority construction of large scale hydropower to meet demands [16,17]. In Turkey, most of the important water power plants have been developed; hence, only a modest increase in the hydroelectric generating capability can be anticipated in the next two decades [18,19].

The share of energy sources in the gross electrical energy generation in year 2003 has been observed as follows; natural gas with 44.41%, hydro with 25.18%, lignite with 16.85%, hard coal with 6.22%, fuel-oil with 6.17, and others 1.17%. Table 2 shows that in 2003, total gross electricity production of Turkey has reached about 140,283 gigawatt hours (GWh), 74.82% of this is produced from thermal power plants (TPPs) and the reminder 25.18% from HEPPs (35,324 GWh) [20,21]. By the year 2010, Turkey is planning to exploit two-thirds of its hydropower potential, aiming to increase hydro-production to about 75,000 GWh/year. By 2020 this will rise to 100,000 GWh/year, and by 2030 it could be 140,000 GWh/year [22].

Turkey has a gross annual hydro potential of 433,000 GWh, which is almost 1% of world total potential (Table 1) [13,16,17,19,23–30]. Its share is about 16% of the total hydropower capacity in Europe [13]. Almost half of the gross potential is technically exploitable, and 28% is economically exploitable [26].

Turkey is divided into 26 surface hydrological basins. Annual average flows of these basins amount to about 186 km^3. While basin yields vary, the Euphrates and Tigris basins account for 28.5% of total potential of the country [31]. Euphrates and Tigris are the biggest river basins with 45% of hydropower plants (HPPs), which have a total of 22 dams and 19 HEPPs. When this project is completed, 55,000 GWh will be generated annually,

Table 2
Electricity production from thermal and hydropower sources according to years in Turkey [16] and [20,21][a]

Year	Thermal (GWh)	Hydropower (GWh)	Total (GWh)	% of hydropower
1950	759	30	789	3.80
1960	1814	1001	2815	35.55
1970	5590	3033	8623	35.17
1980	11,927	11,348	23,275	48.75
1990	34,395	23,148	57,543	40.22
1995	50,621	35,541	86,153	41.25
1999	81,661	34,678	116,339	29.81
2000	93,934	30,879	124,813	24.74
2001	98,563	24,010	122,573	19.60
2002	71,966	44,034	116,000	38.00
2003[a]	104,898	35,324	140,283	25.18

[a]Refs. [20,21].

Table 3
Dam projects in operation and under construction in Turkey [31]

Projects	In operation			Under construction		
	By DSI	Other	Total	By DSI	Other	Total
Large dams	201	11	212	85	1	86
Small dams	343	—	343	124	—	124
Irrigation (million ha)	2.77	2.12	4.89	0.80	—	0.80
Water supply (billion m^3)	2.50	0.46	2.96	1.09	—	1.09
Flood control area (million ha)	1.0	—	1.0	0.50	—	0.50

45% of the total exploitable portion [17,23]. The largest HPPs of Turkey are Atatürk (2400 MW), Karakaya (1800 MW), Keban (1330 MW), Altinkaya (700 MW), Birecik (672 MW), and Berke (510 MW).

In the beginning of 1999, the construction of 193 dams had been completed and put in the operation. Fifty-five HEPPs associated with dams or canals rivers constructed by the State Hydraulic Works (DSI in Turkish initials) have total installed capacity of 10,537 MW (34,678 GWh). When HEPPs constructed by other organizations are considered, there are 104 HEPPs in operation, and annual average energy of 37,079 GWh. This figure is equivalent to 30% of the total economic hydroelectric potential of Turkey by 1999 [16]. In 2000, there were 120 HEPPs in operation, with 34 more under construction. Ultimately, 329 more HEPPs are projected to make use of remaining hydro potential generation of 69,326 GWh/year [28,29] and [32]. At the end of 2002, this figure reached 134 HPPs in operation having a total installed capacity of 44,034 GWh generating about 38% of the total electricity (116,000 GWh) production in Turkey [16].

Turkey has totally constructed 559 dams by 2005, which are now in operation. Of these 559 dams, 212 facilities have been constructed as large dams and 343 as small dams, as given in Table 3 [31]. Eighty-two HEPPs of 134 are large dams and each has an installed capacity more than 2 MW. This figure will soon reach 40% of the total potential when the projects of 37 dams (4057 MW), which are under construction are completed (Table 4).

Table 4
Distribution of the hydroelectric power potential in Turkey by project implementation status [16,17]

Present status of HEPPs project	Number of project	Installed capacity MW	Total annual power generation capacity				
			Firm GWh	Mean GWh	Mean %	Cumulative GWh	Cumulative %
In operation[a]	114	10,537	29,836	34,678	29	34,678	29
Under construction	37	4057	7,897	13,368	11	48,016	40
Final design completed	16	3637	7,456	11,325	9	59,371	49
Under final design preparation	13	1208	792	3768	3	63,139	52
Planned	95	4794	9510	17,380	14	80,519	66
Under planning	28	1918	3347	9916	8	90,435	74
Master plan completed	57	3503	7589	12,742	10	103,177	84
Reconnaissance completed	123	4935	11,204	19,145	16	122,322	100
Total potential	483	34,592	78,631	122,322	100		

[a]This figure rose about 134 dam and installed capacity is 12,177 MW in 2002.

There are 13 large-scale HPPs, with the total installed capacity of each plant up to 120 MW generating amount of 30,000 GWh/year of the total 44,034 GWh/year electricity generation of the country [16,17]. The main objective in doing the present study is to investigate the sustainable development of Turkey's SHP plants.

3. Small hydropower plants in Turkey

3.1. Turkey's small hydropower potential

There is a proposal of the project called "HYDROPOT" submitted for FP6 (the 6th Framework Programme) funding in order re-evaluate hydropower potential. The gross theoretical SHP potential of Turkey is 50,000 GWh/year. The technically and economically feasible potential is 30,000 and 20,000 GWh/year, respectively. A huge untapped potential exists for SHP plant in Turkey. Only 3.3% of economically feasible potential is developed so far. Table 5 shows Turkey's SHP potential [33].

3.2. Brief historical development of SHPs in Turkey

Development of SHP began in 1902 in Turkey. Since then, municipalities in rural areas have installed many decentralized plants by private entrepreneurs, and by some government organizations [17,29,34,35]. The first small hydroelectric plant (SHEP) with a capacity of 88 kW was installed in Tarsus-Adana, Turkey in 1902. In the period of the Republic of Turkey, the utilization of hydroelectric power was first initiated in 1929 with the establishment of the Visera power plant with a capacity of 1 MW in the city of Trabzon. A number of SHEPs were built to meet the increasing demand on electricity from

Table 5
Turkey's small hydropower potential [33]

Potential	Generation		Capacity (MW)
	GWh/year	%	
Gross theoretical	50,000	100	16,500
Technically feasible	30,000	60	10,000
Economically feasible	20,000	40	6500
Economically feasible potential that has been developed	664	3.3	175
Remaining economically feasible potential	19,336	96.7	6325
Remaining economically feasible potential taking into account environmental constraints (for example, rivers exempted from damming)	~19,300	96.7	6325

Table 6
Small hydropower development in Turkey during 1995–2002 [33]

	1995	1996	1997	1998	1999	2000	2001	2002	Forecast	
									2010	2015
Total number of SHP	52	55	56	59	61	67	70	71	100	130
Capacity (MW)	124.9	137.7	138.6	144.1	146.3	170.2	175.5	177.1	260	335
Generation (GWh)	439	499	500	524	533	636	664	673	968	1250

1950 to the 1960s, reaching a total installed capacity of 38 MW in 1955 [6]. Temelsu is a well-known Turkish consulting engineering company, which provides multi-disciplinary engineering services, locally and internationally, since its foundation in 1969 [29,35].

In later years, it was understood that the payback periods for these SHEPs were not economically feasible. Therefore, the larger HEPPs were begun to be installed. Following the two oil crises of the 1970s the SHEPs started to rebuild [6]. By the end of 1998, the total number of SHP stations in operation throughout the country was 59 with a total installed capacity 156.73 MW, about 1.6% of the total hydropower potential (9497.85 MW) in Turkey [29,30,36].

3.3. Recent perspectives of SHPs in Turkey

In 2002, these figures have reached 71 small plants and 177.1 MW (673 GWh), respectively. Table 6 shows situation of SHP development in Turkey during 1995–2002. The bulk of all SHP plants are constructed recently in Turkey, within a period of 20 years (Table 7). Around 20% of generating capacity of SHPs is in private hands. According to their gross head the percentage of SHPs is as follows: low head (up to 5 m)—0%; Medium head (5–15 m)—5% and high head (more than 15 m)—95%. High head SHPs are mostly exploited in Turkey [33].

Total installed projects capacity of SHP is 2.45% and the total energy potential is about 2.96%, which have installed capacity less than 10 MW. At the end of 2002, about 98.5% of

Table 7
Age structure of SHPs [33]

	0–19-year old	20–39-year old	40–59-year old	>60-year old	Total
Number of SHP	61	4	6	0	71

the all ready-exploited potential is from dams and HEPPs, and the remainder is from run-off river and canal SHP. Six SHP projects are under construction and 127 SHP projects are still considered at various stages of the projects, which are in final design stages or in feasibility stages. Some SHPs, including run of rivers systems in operation and installed capacity less than 10 MW, are given in Table 8. There are intensive investigations to improve the small and large hydropower development in Turkey. For putting this aim into practice, some of SHPs are still under construction or under development in Turkey (Table 9). However, until now, as a result of rapid increase in the field of energy consumption, the priority has been given to development of large-scale hydropower projects to recover increasing energy demand and to provide maximum energy to the country's economy. Some research projects have been conducted to progress the uses of small hydroelectric power in Turkey. During 25 years, the average annual increase of SHP capacity was 8–12% [17].

Some of this potential can be achieved with SHEPs having individual capacities of 10 MW or less. Many adverse effects of large hydroelectric projects on the environment and local people can be prevented or reduced if SHPs are used. The use of SHEPs causes minimal changes in natural habitats. Protection against floods and droughts can be achieved easily. On the other hand, SHEPs not only provide electricity and water for both irrigation and drinking purposes but they also create job opportunities in rural areas and thus can prevent migration to cities. They provide significant forward and backward linkages. Increasing demand for power generating turbines and other equipment will benefit the industrial sector and reduce import demand. Therefore, the use of SHEPs is important for sustainable development and economic growth for Turkey [25].

4. An overview of SHPs

An SHP design should be the result of the work of a multi-disciplinary engineering or multi-specialist team including hydrologic, hydraulic, structures, electric, mechanical, geologic and environmental experts. They can not be scaled down from large projects. Several types of SHP layout schemes are characterized essentially through different intakes and diversion structures depending on the type of the conveyance system (e.g. total pressurized or mixed) [37]. The SHPs include some essential components are penstock, power house, tailrace, generating plant and allied equipment [11]. Fig. 1 shows small hydro system.

The two small-scale hydropower systems that are being discussed in this section are the sites with capacities below 100 kW (referred to as micro hydropower (MHP) systems) and sites with capacity between 101 kW and 1 MW (referred to as SHP systems). MHP systems, which use cross flow turbines and pelton wheels, can provide both direct mechanical

Table 8
Some SHPs including run of river systems in operation and installed capacity less than 10 MW [45]

Dam's name	River name	Site name	Development status	Installed capacity (MW)	Annual generation capacity (GWh)	Yield (m^3/kWh)
Anamur	D. Akdeniz	Icel	Dev	0.84	3.0	16.70
Atakoy	Yesilirmak	Tokat	Dev	4.80	8.0	3.55
Berdan Hes	Tarsus	Icel	Dev	10.00	48.0	—
Bereket	—	Denizli	Dev	3.20	26.0	—
Bereket Enerji	—	Aydin	Dev	8.90	32.0	—
Botan	Dicle	Siirt	Dev	0.60	7.0	112.50
Bozyazi	D. Akdeniz	Icel	Dev	0.49	1.5	13.60
Ceyhan	Ceyhan	K.Maras	Dev	3.60	12.0	16.00
Dere	—	Konya	Dev	0.44	1.5	—
Derme	—	Malatya	Dev	5.00	34.0	—
Durucasu	Yesilirmak	Amasya	Dev	0.80	3.0	—
Duzpan Aga	—	Bolu	Dev	1.00	7.5	—
Engil	Van Kapali	Van	Dev	4.60	14.0	—
Ercis	Van Kapali	Van	Dev	0.80	1.5	—
Ermenek	—	Konya	Dev	1.12	0.4	—
Girlevik	Firat	Erzincan	Dev	3.04	18.0	3.10
Gulnar Zeyne	D. Akdeniz	Icel	Dev	0.33	2.4	—
Hakkari Otluca	—	Hakkari	Dev	1.28	2.5	—
Hasanlar	Melen	Bolu	Dev	9.60	42.0	8.813
Hazar II	Hazar	Elazig	Dev	10.00	64.0	—
Ivriz	—	Konya	Dev	1.00	3.0	—
Karakoy	Susurluk	Kutahya	Dev	2.56	7.0	2.75
Karel Enerji	—	Sakarya	Dev	9.30	42.3	—
Kernek	—	Malatya	Dev	0.83	2.2	—
Kepez II	—	Antalya	Dev	5.80	21.0	—
Kisik	Ceyhan	K.Maras	Dev	9.60	32.0	3.05
Kiti	Aras	Kars	Dev	2.76	12.0	26.80
Kockopru	—	Van	Dev	8.80	25.0	—
Kovada I	Aksu	Isparta	Dev	8.25	3.0	—
Kuzgun	—	Erzurum	Dev	2.30	9.2	—
Molu	—	Kayseri	Dev	2.80	20.4	—
Murgul I	—	Artvin	Dev	3.00	9.0	—
Mut	—	Icel	Dev	0.88	3.5	—
Seyhan II	Seyhan	Adana	Dev	7.20	27.0	—
Sizir	—	Sivas	Dev	6.78	50.0	2.80
Su Enerji	—	Bilecik	Dev	5.00	34.0	—
Turuncova	Alakir Cayi	Antalya	Dev	0.55	1.0	—
Visera	—	Trabzon	Dev	1.00	3.0	—
Yureyir	Seyhan	Icel	Dev	6.00	21.0	—
Zernek (Hosap)	Van Kapali	Van	Dev	3.50	13.0	6.50

energy (for crop processing) and electrical energy. MHP systems are sometimes described as those having capacities below 100 kW, mini HPPs are those ranging from 100 to 1000 kW and SHPs are those that produce from 1 to 30 MW [38].

Table 9
Some small hydropower sites (<10 MW-yet undeveloped) under construction or final design completed/under final design in Turkey [13,17][a]

Dam's name	River name	Site name	Development status	Installed capacity (MW)	Annual generation capacity (GWh)
Alpu	Alpu	Tokat	Undev	—	—
Atasu	Degirmen	Trabzon	Undev	5.0	27
Bahceli	Zamantı	Kayseri	Undev	7.0	35
Bogazkoy[a]	—	Bursa	Undev	10.0	27
Cildir II	Aras	Kars	Undev	8.7	15
Imranli	Imranli	Sivas	Undev	3.0	11
Korpuler	—	Van	Undev	2.16	14
Kumkoy[a]	—	Samsun	Undev	10.0	65
Lamas IV	Lamas	Icel	Undev	—	—
Sirma	—	Aydin	Undev	7.2	28
Timarli	—	Cankiri	Undev	8.21	61
Tohma	Tohma	Malatya	Undev	—	—
Tortum II	—	Erzurum	Undev	—	—
Yahsihan	Kizilirmak	Ankara	Undev	7.5	44
Yenicekent	—	Aydin	Undev	—	—
Civril	Kufi	Denizli	Undev	3.0	10
Gokbel	Cine	Aydin	Undev	6.0	25

[a]Ref. [17].

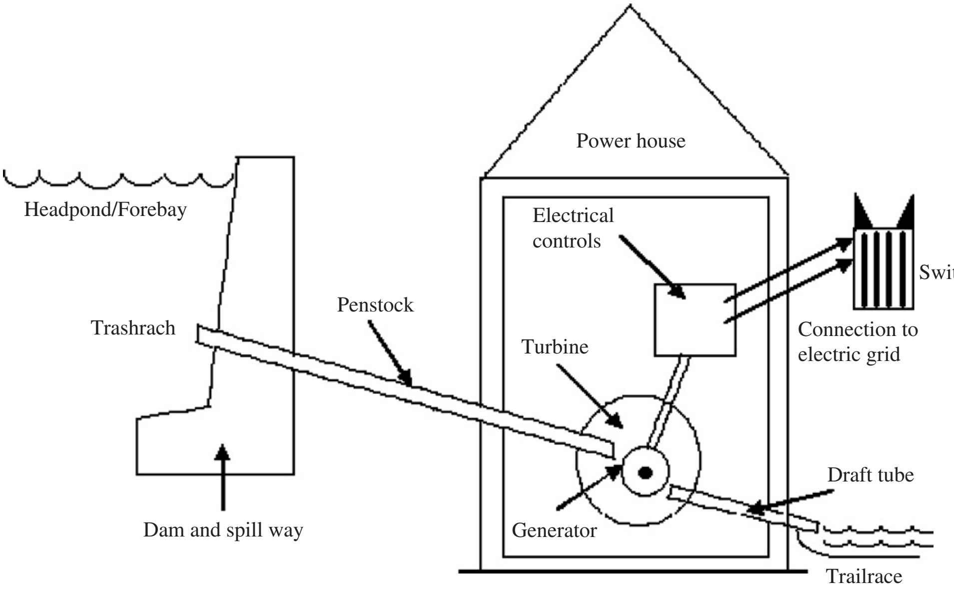

Fig. 1. Small hydro system.

Head is described as the vertical distance, or as a function of the characteristics of the channel or pipe. Most SHP sites are categorized as a low or high head. Low head refers to a change in elevation of less than 10 ft (3 m). A vertical drop of less than 2 ft (0.6 m) will

probably make a small-scale hydroelectric system unfeasible [17]. The net head (H_0) of an SHP can be created in quite number of ways, being the most known the following two types: building a dam across a stream in order to increase the water level just above the plant; or diverting part of the stream, with a minimum of head loss, to just above the plant. Fig. 2 shows components of a hydropower scheme. The basic hydropower principle is based on the conversion of a large part of the gross head, H_g (m), (i.e. net head H_0 (m)) into mechanical and electrical energy [39]:

$$H_0 = H_g - \Delta H_{AB} \tag{1}$$

being head losses along the total conversion system expressed by ΔH_{AB} (m).

The hydraulic power P_0 (kW) and the corresponding energy E_0 (kWh) over an interval time $\Delta t(h)$ will be, respectively:

$$\begin{aligned} P_0 &= \rho g Q H_0, \\ E_0 &= \rho g Q H_0 \Delta t, \end{aligned} \tag{2}$$

where Q (m^3/s) is the discharge diverted to the power plant.

The final power (P_F) delivered to the network is smaller than the available hydraulic power (P_0):

$$P_F = \eta P_0, \tag{3}$$

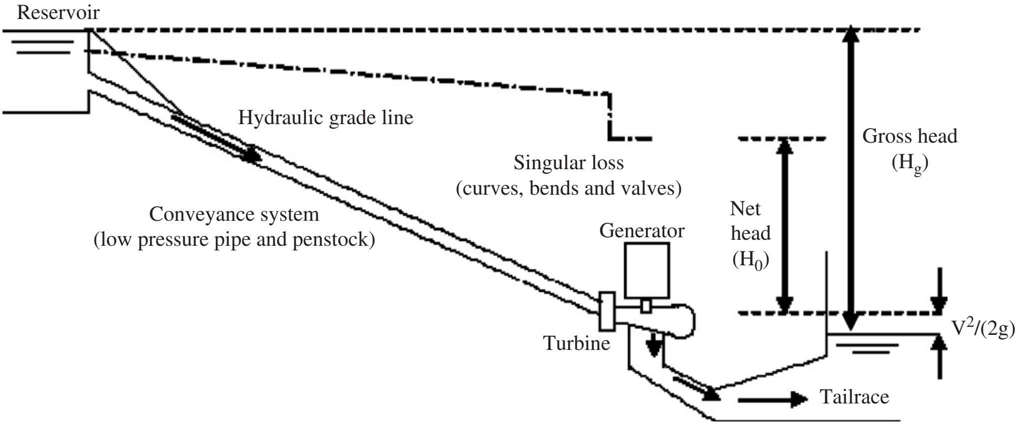

Fig. 2. Components of a hydropower scheme [39].

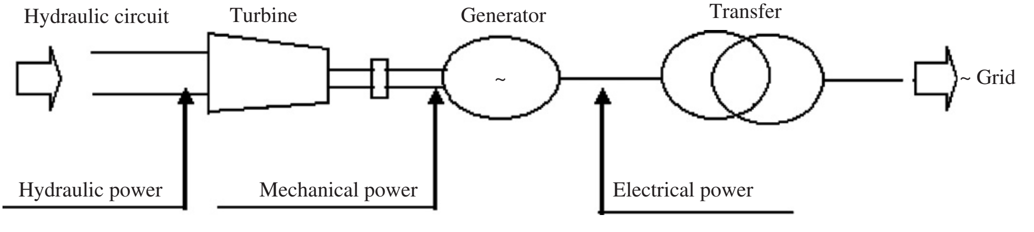

Fig. 3. Power conversion scheme [39].

Table 10
Unit energy cost (1US$–€) [17] and [41]

Technology group	€ cents/kWh (electricity)	
	Unit cost 1995	Unit cost 2020
Fossil fuel/centralized electricity	4–6	—
Fossil fuel/decentralized electricity	8–12	—
Large hydro	3–13	2.6–11.2
Small hydro	4–14	3.6–10.1
Wave/tidal	6.7–17.2	6.1–11
Residues	4–10	2.5–6
Energy crops	10–20	4.5–13
Wind generators	5–9.8	2.5–7.3
Solar thermal	20–24	8–10
Solar PV	31–29	8–22
Wastes	4–5	4–6
Geothermal	5–8	5–7

where η is the global efficiency, resulted of the multiplication of partial efficiencies from the successive transport and conversion phases ($\eta < 1$) (Fig. 3).

Cost of hydropower is affected by the discount rate to a greater extent than that of thermal and nuclear power [40]. Unit costs of SHPs generally are not high compared to the units' cost of other systems. SHP is directly connected with the economic position of the small hydro energy to the other sources of energy. The cost of hydroelectric systems, which typically last for a long time, is low, and in many cases, maintenance is not expensive. In developed countries, each unit energy cost has been compared with the other energy unit cost of new equipment. A prospect for renewable energy in 30 European countries that has been established from 1995 to 2020 shows that the hydropower is one of the few economical significant renewable sources of energy [17,41]. It is estimated that if the unit cost of small hydro energy should decrease by 20% hydropower, it will represent 13% of the renewable energy exploited in 2020 (Table 10) [17].

5. Environmental aspects

An HPP is in general a highly effective energy conversion system. There is no pollution of the environment, but objections are raised relative to the flooding of valuable real estate and scenic areas [42,43]. Hydropower plays a major role in reducing greenhouse gas emissions in terms of avoided generation by fossil fuels. Hydro is a relatively small source of atmospheric emissions compared with fossil-fired generating options. Hydropower also avoids the substantial impact of particulate emissions (fly ash, for example): the costs to human health in the form of respiratory disease are a very tangible impact of this problem. A recent estimate of the environmental cost of this form of pollution is put at US$ 100–500/t/year [44].

Turkey has substantial renewable energy resources especially hydroelectric power and it is currently constructing a series of dams and HEPPs. As Turkey looks towards possible European Union membership, it will need to continue utilizing this cleaner energy as a

Table 11
Resistances to SHP development [33]

Impact	Degree of gravity (1 = no impact, 5 = severe impact)
Visual impact	1
Fishery	1
Water regulation	1
Competition with other uses of water (irrigation)	3
Other kinds of resistance	1

Table 12
Effect on SHP development and operation of the forbidden rivers, EIA, compensation flow, EU water framework directive and other specific EU environmental regulations [33]

Forbidden rivers for hydropower construction[a]	Environmental impact assessment (EIA)	Compensation flow (CF)	EU WFD and other specific EU environmental regulations
There are no rivers forbidden for damming	EIA must be carried out for hydropower projects larger than 10 MW. Between 10 and 50 MW a preliminary IEA is required. Full EIAs are required for storage facilities having reservoir surface more than 15 km^2 and reservoir volumes of more than $100 \times 10^6\,m^3$.	Compensation flow is set depending on flow duration curve and hydro-biological parameters. The losses in SHP electricity production resulting from maintaining CF could be estimated between 5% and 10%	Not applicable

[a]Except conventional protected areas—strict nature reservations or protected areas with overall restricted economic regime.

means to achieve sustainable economic development. Turkey also has a great degree of potential for energy efficiency improvements [29,30]. Tables 11 and 12 show the existing resistances to SHP development and other environmental restrictions in Turkey. These can be viewed as very liberal by comparing with those in other analyzed countries except existing relatively tough competitor irrigation and relatively high compensation flow for SHPs. The latter incurs significant losses in electricity production [33].

6. Conclusion

In 2003, electricity production reached 140,283 GWh while in 1970 it was only 8623 GWh. The sharp growth of the Turkish energy sector has been accompanied by institutional reforms. One of the most important developments has been liberalization of all energy sectors, including electricity production and distribution, to private capital both national and foreign. Over the next there decades, it is expected that many foreign

investors and financiers will be interested in the Turkish hydropower market. Turkey plans to increase hydropower production in the near future.

There are intensive investigations to improve the small and large hydropower development in Turkey. In 2002, Turkey's SHP figures have reached 71 small plants and 177.1 MW (673 GWh), respectively. Total installed projects capacity of SHP plant is 2.45% and the total energy potential is about 2.96%, which have installed capacity less than 10 MW. At the end of 2002, about 98.5% of the all ready-exploited potential is from dams and HEPPs, and the remainder is from run-off river and canal small HPP.

References

[1] Demirbas A, Demirbas AS, Demirbas AH. Global energy sources, energy usage, and future developments. Energy Sources 2004;26:191–204.
[2] Demirbas A. Biomass resources for energy and chemical industry. Energy Educ Sci Technol 2000;5:21–45.
[3] Kwant KW. Renewable energy in The Netherlands: policy and instruments. Biomass Bioenergy 2003;24:265–7.
[4] Edinger R, Kaul S. Humankind's detour toward sustainability: past, present, and future of renewable energies and electricity power generation. Renew Sustainable Energy Rev 2000;4:295–313.
[5] Sadettanhand K, Kumar S. Renewable energy resources potential in Lao PDR. Energy Sources 2004;26:9–18.
[6] Hepbasli A, Ozgener O. Turkey's renewable energy sources: Part 1. Historical development. Energy Sources 2004;26:961–9.
[7] Ozgener O. A review of blade structures of SWTSs in the Aegean region and performance analysis. Renew Sustainable Energy Rev 2005;9:85–99.
[8] Akdeniz RC, Acaroglu M, Hepbasli A. Cotton stalk as a potential energy source. Energy Sources 2004;26:65–75.
[9] Muneer T, Maubleu S, Asif M. Prospects of solar water heating for textile industry in Pakistan. Renew Sustainable Energy Rev 2006;10:1–23.
[10] Binder J. Small hydroelectric power plants: a most efficient contribution to renewable energy, Karntner Elektrizitats Aktiengesellschaft (KELAG). Sixty International Summer School Solar Energy. Applications—Sustainable Energy Issues, University of Klagenfurt, Klagenfurt/Carinthia, Austria, 2000. p. 204–14.
[11] Dragu C, Sels T, Belmans R. Small hydro power-state of the art and applications. International Conference Power Generation and Sustainable Development (AIM), Liege, Belgium, 2001. p. 265–70.
[12] Lako P, Eder H, de Noord M, Reisinger H. Hydropower development with a focus on Asia and Western Europe, Overview in the framework of VLEEM 2. project, Project Number: 7.7372, ECN Policy Studies and Verbundplan, Austria, 2003.
[13] General Directorate of State Hydraulic Works (DSI), Energy: hydroelectric energy, 2005 (http://www.dsi.gov.tr).
[14] Bergkamp G, McCartney M, Dugan P, McNeely J, Acreman M. Dams, ecosystem functions and environmental restoration, prepared for the world commission on dams (WCD). Environmental Issues II.1, Vlaeberg, Cape Town 8018, South Africa, 2000.
[15] International Energy Agency (IEA), Renewables information, 9, rue de la Fédération, 75739 Paris, cedex 15, France, 2003.
[16] Demirbas A, Bakıs R. Turkey's water resources and hydropower potential. Energy Exploration Exploitation 2003;21:405–14.
[17] Bakıs R, Demirbas A. Sustainable development of small hydropower plants (SHPs). Energy Sources 2004;26:1105–18.
[18] Kaygusuz K. Sustainable development of hydropower and biomass energy in Turkey. Energy Convers Manage 2002;43:1099–120.
[19] Hepbasli A, Ozgener O. Turkey's renewable energy sources: Part 2. Potential and utilization. Energy Sources 2004;26:971–82.
[20] Republic of Turkey, Primary Ministry State Institute of Statistics (SIS), The electricity generation and distribution quarterly survey, 2003 Fourth Quarter (October–November–December), Necatibey St. No: 114, Yucetepe, Ankara, Turkey, 2004 (http://www.die.gov.tr).

[21] Balat M, Balat H, Acici N. Thermal- electricity power plants (TPPs) in Turkey. Energy Exploration Exploitation 2004;22:367–76.
[22] Kaygusuz K. Hydropower and the world's energy future. Energy Sources 2004;26:215–24.
[23] Kaygusuz K. Hydropower potential in Turkey. Energy Sources 1999;21:581–8.
[24] Kaygusuz K. Sustainable development of hydroelectric power. Energy Sources 2002;24:803–15.
[25] Demirbas A. Electricity from biomass and hydroelectric development projects in Turkey. Energy Exploration Exploitation 2002;20:325–35.
[26] Oğulata RT. Energy sector and wind energy potential in Turkey. Renew Sustainable Energy Rev 2003;7:469–84.
[27] Demirbas A, Bakıs R. Energy from renewable sources in Turkey: status and future direction. Energy Sources 2004;26:473–84.
[28] Balat M. The use of renewable energy sources for energy in Turkey and potential trends. Energy Exploration Exploitation 2004;22:241–57.
[29] Balat M. Turkey's hydropower potential and electricity generation policy overview beginning in the twenty-first century. Energy Sources 2005;27:949–62.
[30] Balat M. Current hydropower potential in Turkey and sustainability of hydropower for Turkey's energy demand. Energy Exploration Exploitation 2005;23:1–18.
[31] General Directorate of State Hydraulic Works (DSI), Land and water resources, 2005 (http://www.dsi.gov.tr).
[32] Energy Information Administration (EIA), Turkey country analysis briefs, Washington, DC, USA, 2002.
[33] European Small Hydropower Association (ESHA), Small hydropower situation in the new EU member states candidate countries, thematic network on small hydropower (TNSHP) project, Renewable Energy House, Rue du Trone 26, 1000 Brussels, Belgium, 2004 (http://www.esha.be).
[34] Hepbasli A, Ozdamar A, Ozalp N. Present status and potential of renewable energy sources in Turkey. Energy Sources 2001;23:631–48.
[35] Demirbas A. Sustainable developments of hydropower energy in Turkey. Energy Sources 2002;24:27–40.
[36] Turkish Electricity Generation and Transmission Company (TEAS), Electricity generation transmission statistics of Turkey, APK-377, Ankara, Turkey, 1999.
[37] Ramos HE, Almeida AB. Small hydro as one of the oldest renewable energy sources, water power and dam construction. Small Hydro, Lisbon, Portugal, 2000.
[38] Demirbas A, Demirbas AS, Demirbas AH. Turkey's natural gas, hydropower, and geothermal energy policies. Energy Sources 2004;26:237–48.
[39] Ramos HE, Almeida AB. Small hydropower schemes as an important renewable energy source, Publicacao com Referee International, Hidroenergia 99, Vienna, Austria, 1999.
[40] Mariusson JM, Thorsteinsson L. Study on the importance of harnessing the hydropower resources of the world, UNIPEDE's (International Union of Producers and Distributors of Electrical Energy) XXIV Congress, Montreux, Switzerland, May 1997.
[41] Kueny JL. Part I, Objectives for small hydro technology, Institute National Polytechnique de Grenoble, B.P. 53-38041-Grenoble Cedex 9-France, 2003. p. 1–35 (http://www.small-hydro.com).
[42] Kaygusuz K. Energy situation, future developments, energy saving, and energy efficiency in Turkey. Energy Sources 1999;21:405–16.
[43] Balat M. Usage of energy sources and environmental problems. Energy Exploration Exploitation 2005;23:141–68.
[44] World Energy Council (WEC), Survey of Energy Resources: Hydropower, 5th Floor, Regency House, 1–4 Warwick Street, London, UK, 2001.
[45] General Directorate Electrical Power Resources Survey and Development Administration (EIE), HPP Projects: Production Characteristics of the HPPs in Operation, Cankaya, Ankara, Turkey, 2005 (elektriketut@eie.gov.tr).